DISTRIBUTION OF RAINFALL AT KNOXVILLE, TENN., BY HOURS, WEEKS, AND MONTHS OF FOUR WEEKS

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The basis for this study is the hourly precipitation, including snowfall, for 27 years, 1898–1924 inclusive, as recorded at Knoxville, Tenn.

It seemed desirable to include the snowfall in order that the weekly values might be as accurate as possible, as the snowfall amounted on the average to between 1 and 2 per cent of the annual precipitation.

The hourly values were pretty carefully estimated for the daylight hours, and when such an estimate could not be made the total for any known period was prorated evenly among the several hours. The only appreciable effect of including snowfall would be a slight smoothing of the hourly amounts. As it was found necessary to smooth the data still further before a chart could be made that would resonably represent what we would expect to find, if we had a much longer record, it is believed that the inclusion of snowfall has not vitiated the final result as shown in Table 1, and in Figure 5.

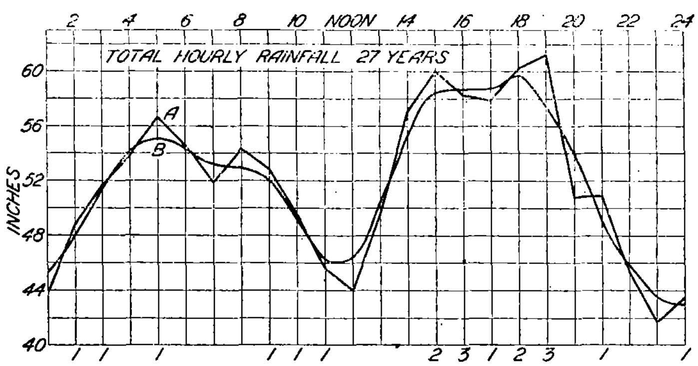

FIG. 1.—Total hourly precipitation in 27 years. Curve A, actual precipitation; curve B, smoothed curve. Figures at bottom, number of times with an inch or more, in 27 years

The object of the study was twofold. The first objective was to get some definite information about the rate of rainfall through the day and through the year, that would be of practical value in answering questions about rainfall insurance. The second objective was to make a comparison between our present calendar of 12 unequal months and the proposed calendar of 13 months of four weeks each, as a basis for studies of this kind. In this study February 29 and December 31 were ignored entirely. The data considered were total rainfall and the number of hours in which there was rain.

The rainfall for each hour of January first for 27 years was entered on one sheet and totals obtained for each hour. A similar sheet was made for each of the other days of the year, or 364 in all. The totals from these sheets were copied in groups of seven and added, giving weekly totals for each hour of the day. These in turn were grouped in fours, giving 13 monthly totals, and the sum of these gave the annual total for each hour of the day for the 27 years.

The number of hours on which rain occurred was treated in exactly the same way. These sheets were also added horizontally as a check and to obtain weekly and monthly values.

We will discuss first the hourly values and later the values for the week and the month.

The total rainfall per hour for the 24 hours of the day for 27 years is shown in Figure 1, by curve A. When it is considered that the record covers 9,828 days, and that of this number rain fell on about 700 on the average for each hour of the day, we may feel that this line represents the real distribution pretty accurately. But, on the other hand, we must remember that occasionally there is a rainfall of more than an inch in one hour, and that these heavy rains are comparatively few and very unevenly distributed. There were 19 hours during the 27 years in which 1 inch or more of precipitation was measured. These hours are indicated by the numbers at the bottom of Figure 1. It will be noted that several of these occurred during wet hours when their omission would have helped to smooth the curve, but others occurred during the dry hours when their omission would have made the curve still more irregular. This distribution indicates the chance character of these heavy rains. This

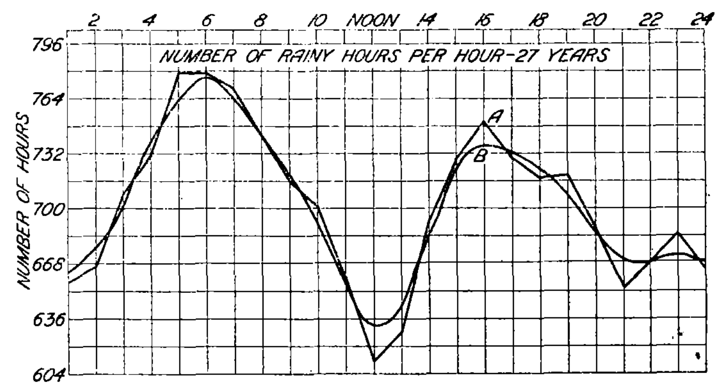

FIG. 2.—Number of hours with precipitation for each hour of the day in 27 years. Curve A, actual number of hours; curve B, smoothed curve

being the case it seemed proper to smooth the curve somewhat and the formula $\frac{1+2+3}{3}=2$, was used and the resulting curve is represented in Figure 1 by curve B. This probably represents as nearly as possible the average distribution of rainfall through the 24 hours of the day at this station.

It may be of interest to note here that the rainfall for the 12 hours from 6 a. m. to 6 p. m. is 51.5 per cent of the total for the 24 hours.

Figure 2, shows the total number of hours for each of the 24 hours of the day in which precipitation occurred. Curve A represents the actual number of hours and curve B the same data after applying the formula $\frac{1+2+3}{3}=2$. It is believed that here as in Figure 1, the minor variations are subject enough to chance to warrant this amount of smoothing.

The curves for total precipitation and duration are quite similar in a general way, but differ somewhat in details. The primary maximum for duration is in the morning and the primary minimum at noon, while the primary rainfall maximum is in the afternoon and the lowest minimum about midnight.

Dividing the total rainfall by the number of hours, the rate or average amount of rain per rainy hour was obtained. Figure 3, represents the smoothed values of rainfall and number of rainy hours as percentages of their respective totals, and also the rate per hour in thousandths of an inch. This rate shows a rapid increase shortly after

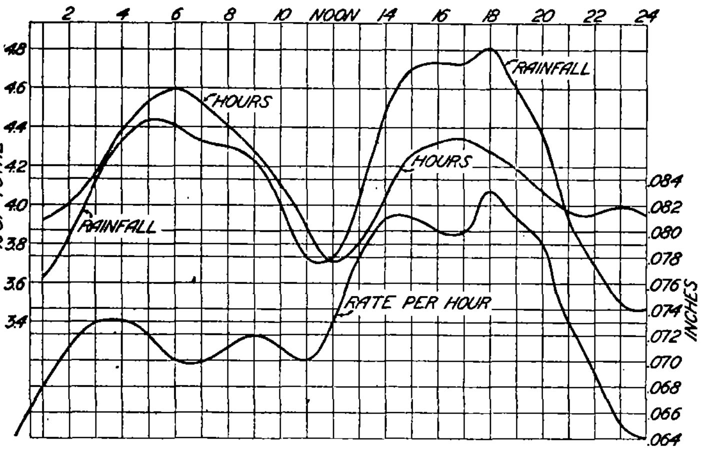

FIG. 3.—Curve A, per cent of total precipitation per hour; curve B, per cent of total number of hours with precipitation per hour; curve C, equals A divided by B, equals rate per hour in thousandths of an inch

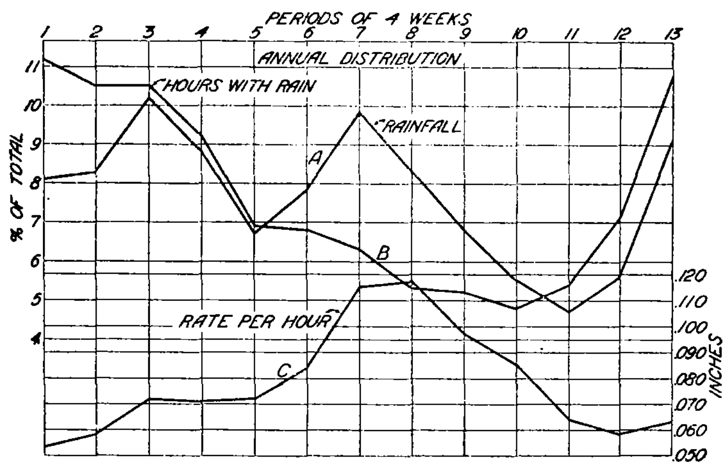

FIG. 4.—Annual distribution of precipitation in periods of four weeks. Curve A, per cent of total precipitation in each period; curve B, per cent of total number of hours with precipitation in each period; curve C, equals A divided by B, equals rate per hour in thousandths of an inch

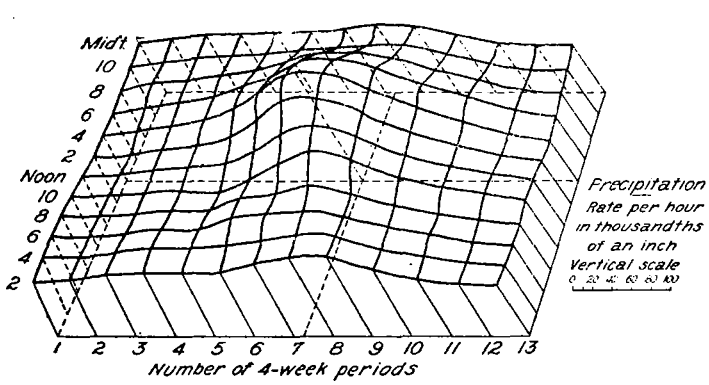

FIG. 5.—Graphic representation of rate per hour through the year in thousandths of an inch, from Table 1

midnight and another at noon followed by a very rapid fall from 6 p. m. to midnight.

In Figure 4, we have three curves representing the monthly per cent of total rainfall and rainy hours, and the rate per hour for each month. We are using here 13 months of 4 weeks each. It will be seen that the high rainfall during the winter and early spring is produced by a large number of hours with a low rate per hour,

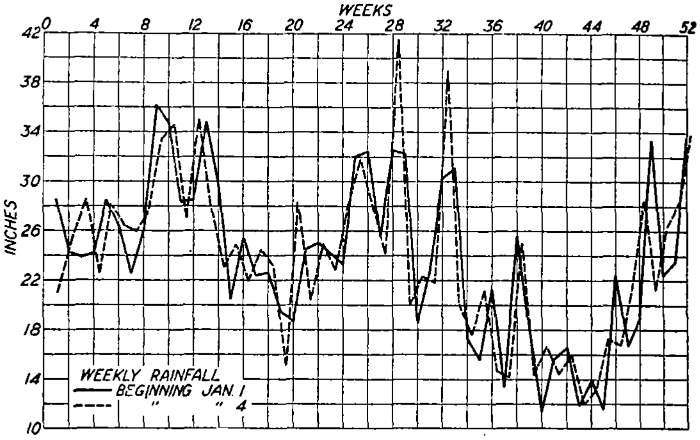

FIG. 6.—Weekly precipitation, total for 27 years. Solid line, 52 weeks beginning January 1; broken line, 52 weeks beginning January 4

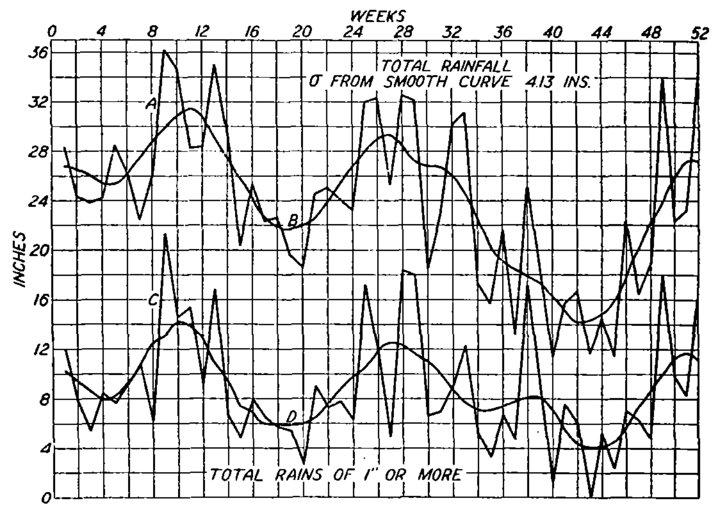

FIG. 7.—Precipitation. Curve A, total weekly; curve B, equals, curve A, smoothed; standard deviation of A from B is 4.13 inches; curve C, total weekly in rains of 1 inch or more; curve D, equals curve C, smoothed

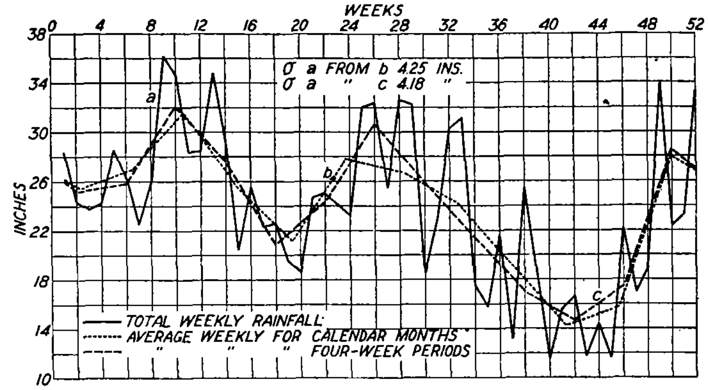

FIG. 8.—Precipitation. Curve A, total weekly; curve B, average weekly for calendar months; curve C, average weekly for periods of four weeks; standard deviation of A from B is 4.25 inches; standard deviation of A from C is 4.18 inches

while the summer maximum is due to a higher rate in a fewer number of hours.

Figure 5, is an attempt to show graphically the rate per hour through the day and through the year as found in Table 1.

For the comparison between the present calendar and the proposed 13-month calendar we will begin with the weekly values. The solid line in Figure 6 gives the total rainfall by weeks for the 27 years. Two sets of variations are seen at once. These are the great variations from week to week, and a longer period variation having two maxima and two minima per year. It is probably safe to assume that the long period variation is real, but just where the curve representing that variation should run depends largely on what we do with the weekly variations. Are they real or accidental? As one way of testing the matter a new set of weekly values was computed beginning on January 4, or three days later than in the first instance. These values are represented by the broken line in Figure 6. This shifting of the week made but little change in the curve although the phase was reversed in a few minor cases. An inspection of the data showed that in some cases at least the high points were due to one or more unusually heavy rains. Following this lead the total precipitation per week in rains of 1 inch or more was computed. These values are shown by curve C in Figure 7. Comparing this curve with the total rainfall curve A above, it is apparent that a very large portion of the weekly variation is due to these heavy rains. It was found that during the 27 years there had been rains of 1 inch or more on 299 days, which is 8.6 per cent of the total number of rainy days. The rainfall for these 299 days was 37 per cent of the total rainfall for the whole period. Even the most imaginative person would hardly assume that in another 27 years similar heavy rains would fall on exactly the same dates or even in the same weeks.

Under these circumstances it seemed proper to eliminate the weekly variations as much as possible without interfering with the general trend and this was done. The data were smoothed twice using first the formula $\frac{1+2+3+4+5}{5}=3$ and then the formula $\frac{1+2+3}{3}=2$. The curves B and D in Figure 7, represent the smoothed values. The standard deviation of the weekly values from the smoothed curve of total rainfall is 4.13 inches.

In Figure 8, Curve A represents the weekly rainfall, curve B the monthly rainfall by calendar months, and the broken line represents the rainfall for 13 periods of 4 weeks each.

The standard deviation of the weekly values from the curve for the calendar months is 4.25 inches, and the standard deviation from the curve of 13 months of 4 weeks each is 4.18 inches, as compared with a standard deviation of 4.13 inches from the smooth curve in Figure 7.

Conclusion. The method of computing data by weeks appears to have an advantage in point of accuracy of nearly 3 per cent over the usual method using calendar months.

TABLE 1.—*Rate per hour for 13 periods of 4 weeks beginning January 1, in thousandths of an inch*

Period	A. M.						P. M.					
	2	4	6	8	10	Noon	2	4	6	8	10	Midnight
1	0.062	0.064	0.063	0.062	0.059	0.057	0.054	0.053	0.052	0.054	0.056	0.059
2	.065	.065	.063	.061	.060	.058	.055	.058	.060	.064	.062	.064
3	.071	.070	.067	.064	.064	.064	.064	.065	.067	.068	.068	.069
4	.073	.076	.073	.069	.067	.069	.069	.072	.073	.074	.071	.070
5	.074	.076	.073	.069	.065	.072	.078	.087	.087	.080	.074	.073
6	.075	.080	.087	.085	.082	.089	.100	.110	.101	.091	.079	.074
7	.086	.087	.093	.090	.101	.110	.124	.131	.119	.101	.081	.078
8	.095	.094	.096	.101	.115	.121	.127	.132	.122	.104	.087	.086
9	.096	.093	.091	.091	.106	.109	.111	.113	.113	.098	.088	.083
10	.080	.077	.078	.079	.086	.086	.088	.091	.093	.083	.076	.073
11	.069	.069	.070	.068	.072	.070	.070	.072	.076	.070	.063	.061
12	.064	.062	.061	.062	.067	.064	.060	.059	.060	.059	.056	.060
13	.063	.060	.058	.057	.059	.057	.054	.051	.053	.055	.057	.061

CORRELATIONS FOR LONG-RANGE FORECASTING

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In Table 1 are listed 13 correlation coefficients, based on from 48 to 50 years' data. Of these, six are equal to or greater than 0.50, and may therefore be useful in long-range weather forecasting. Table 2 shows the actual and the computed deviations from the mean for those years in which the deviations of the disturbing element were especially pronounced. The coefficients are all equal to or greater than six times the probable error.

The North Atlantic circulation is measured by the deviation from normal of the pressure difference between Iceland and the Azores. The figures for the Nile flood are relative numbers, one relative unit being about 4.8 per cent; the mean of the Nile flood at Aswan, July to October, is 670.8×10^8 cubic meters. The temperatures of Germany are the means of 10 stations; those of the United States the means of 5 stations east of the Mississippi—Milwaukee, Cincinnati, New York, New Orleans, and St. Louis. The data were taken from Baur, Grundlagen einer Vierteljahrestemperaturvorhersage für Deutschland (1926); Bliss, The Nile Flood and World Weather (1926); and Groissmayr, Die Nilflut und der Folgewinter in Deutschland (Met. Zeit., 1927).

TABLE 1.—*Correlations for long-range forecasting*

Elements correlated	Charleston precipitation, 1872–1921	Charleston precipitation, 1872–1919	Argentine pressure, April–June, 1874–1923	Argentine pressure, May, 1874–1923	Nile flood at Aswan, July–October, 1874–1923
Nile flood at Aswan, July–October, 1874–1923	[1] 0.61		0.57		
Temperature in eastern United States, September–November, 1874–1923	−0.28			[1] −0.46	−0.40
Temperature in Germany, December–February, 1874–75 and 1923–24	−0.38		−0.47		[1] −0.50
Temperature in Germany, March–May, 1875–1924	[1] −0.55				
North Atlantic circulation (Azores-Iceland), December–February, 1874–75 and 1921–22		[1, 2] −0.66			
North Atlantic circulation, March–May, 1875–1922		−0.40			
Annual precipitation at Charleston, S. C., 1873–1920		[1] −0.64			
North Atlantic circulation, December–February, 1874–75 and 1923–24					−0.49

[1] The closest relations, so far as the author knows, ever found for these elements.
[2] Most important.